The Changing Landscape of Research

A Regulator's Perspective

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Canada

Presentation Outline

- Canadian Nuclear Safety Commission
- Role of research in technology evolution
- Role of regulatory research
- Challenges
- Conclusions

Canadian Nuclear Safety Commission

- Established in May 2000 under the *Nuclear Safety and Control Act*
- Replaced the Atomic Energy Control Board, which was established in 1946 under the *Atomic Energy Control Act*
- Regulates all nuclear-related facilities and activities

Over 70 years of experience

CNSC Mandate

- Regulate the use of nuclear energy and materials to protect health, safety, security and the environment
- Implement Canada's international commitments on the peaceful use of nuclear energy
- Disseminate objective scientific, technical and regulatory information to the public

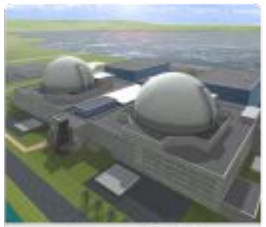
Research Fundamentals

- Research is a necessary and integral part of the evolution of a technology
- The type of research needed varies throughout the lifecycle of a technology
- It is important to have a shared vision for the type of research needed and a clear delineation of roles for conducting the research

Evolution of Technology – Research Focus Areas

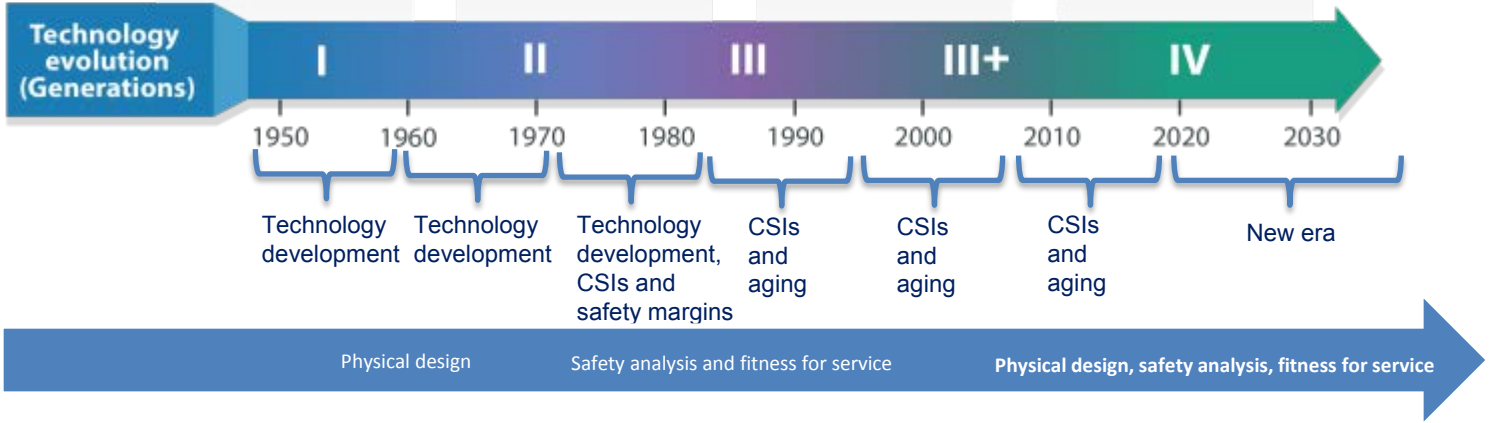
Early prototype reactors
(NPD, Douglas Point)

Commercial power reactors
(Pickering, Darlington, Bruce, Point Lepreau, Gentilly-2)



Advanced Light Water Reactors + evolutionary designs
(EC-6, ACR 1000)

Revolutionary designs
(Molten salt, liquid metal, high temperature gas)



Research – Continuous Learning

Safety culture

Fukushima

NRX

PT and H_2

Chernobyl

Human factors

Readiness?

Windscale

TMI

Fuel deposits

Readiness?

Containment H_2

Barseback

LOCA margins

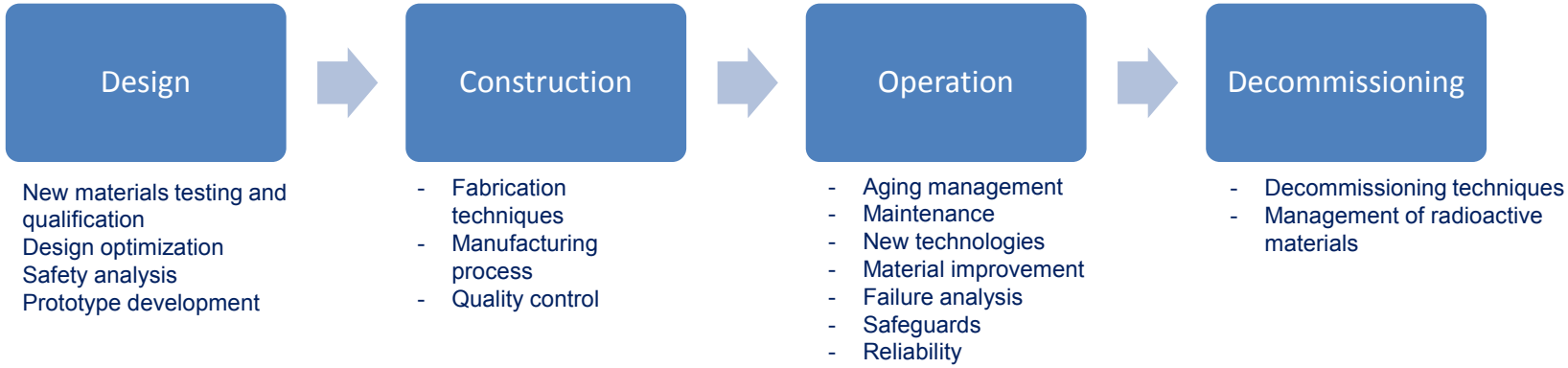
Historical Considerations in Technology Evolution

- Evolving reactor designs incorporate the following:
  - ✓ lessons learned from operating experience, near misses, equipment failures and accidents
  - ✓ an understanding that we are not infallible and must anticipate and prepare for unexpected circumstances
  - ✓ provision for timely access to research capabilities including research facilities and expertise

Research is necessary!

Research During Technology Lifecycle

- During the lifecycle of a technology:
  - ✓ the type of research needed at each stage may be different
  - ✓ research capability should be maintained and research should be available to address emergent concerns and potential changing needs



Integrated Planning and Resourcing for Research

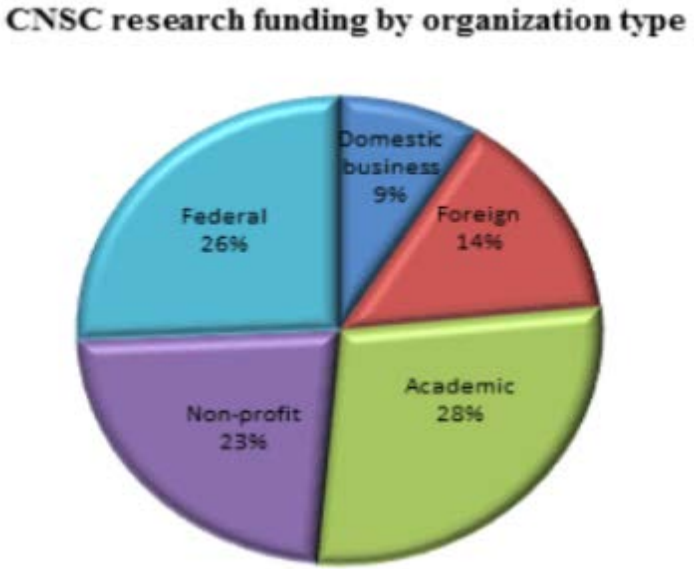
- The success of a new nuclear technology is dependent upon there being a shared vision
- Research must be a part of the vision
- Research requires forethought and uses precious resources
- Vendors, applicants, industry partners and government should consider their respective roles to ensure the right research is done at the right time

Regulator's View of Regulatory Research

Research generates knowledge and information to support CNSC staff in achieving the regulatory mission

- ✓ supports regulatory positions and decisions
- ✓ identifies and assesses the significance of emerging issues
- ✓ supplements staff assessment capabilities
- ✓ contributes to the independence of the regulator
- ✓ reduces uncertainties regarding health, safety, security and environmental issues

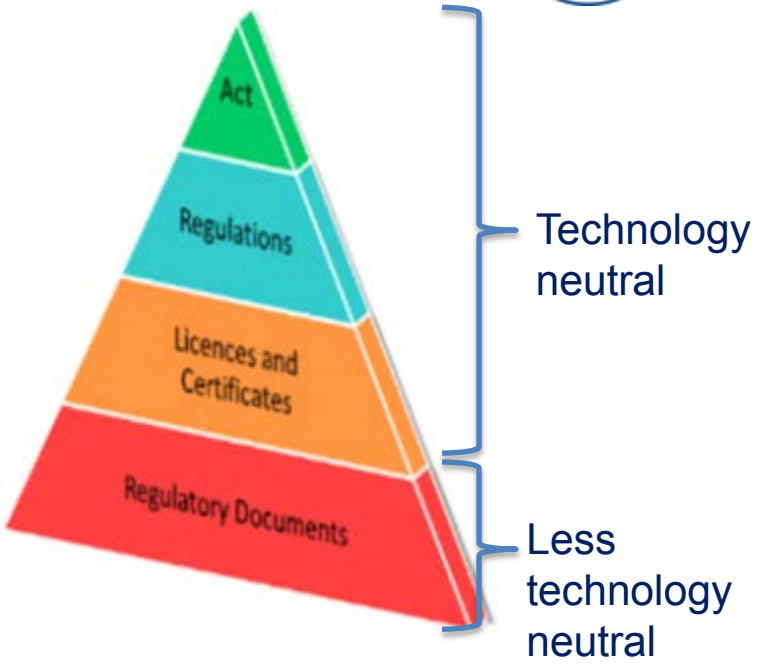
CNSC Regulatory Research Universe



- The CNSC has a modest $3.7M research program
- The CNSC is an active participant in the Organisation for Economic Co-operation and Development/Nuclear Energy Association (OECD/NEA) research, both within the Committee on the Safety of Nuclear Installations (CSNI) working groups and NEA specific projects
- The CNSC is represented on the Federal Nuclear S&T committees with a total budget of $76M

Regulatory Research for Framework Development

- Multiple technologies including light- and heavy-water reactors
- Configured regulatory framework to be technology neutral
  - ✓ regulatory framework is based on water-cooled operating experience (OPEX)
  - ✓ objectives of requirements can be applied to non-water-cooled reactors, with some exceptions



SMR Regulatory Research

- In May 2016, the CNSC published a discussion paper (DIS-16-04) outlining regulatory strategy, approaches and challenges related to small modular reactors (SMRs)
- In 2017, in collaboration with the United States Nuclear Regulatory Commission (U.S. NRC), the CNSC led the development of a technical seminar by Oak Ridge National Laboratory on the Molten-Salt Reactor Experiment (MSRE)
- Currently, the CNSC is working with Oak Ridge National Laboratory and Argonne National Laboratory to develop a technical seminar on sodium-cooled fast reactors
- The CNSC is continuing to enhance knowledge of other SMR technologies by working with international partners – both regulators and national labs

Various SMR Designs Being Reviewed

No.	Country of origin	Company (design)	Reactor type	Elec. output per unit
1	Canada– U.S.	Terrestrial Energy (IMSR-400)	Molten salt (graphite moderated)	200 MWe
2	U.S.– Korea– China	Ultra Safe Nuclear (MMR-5)	High-temperature gas cooled (graphite moderated)	5 MWe
3	Sweden– Canada	LeadCold (SEALER)	Liquid metal cooled - Lead (no moderator - fast spectrum)	3 to 10 MWe
4	U.S.	Advanced Reactor Concepts (ARC-100)	Liquid metal cooled - Sodium (no moderator - fast spectrum)	100 MWe
5	UK	Urenco (U-Battery)	High-temperature gas cooled (graphite moderated)	4 MWe
6	UK	Moltex Energy (SSR-W300)	Molten salt (no moderator - fast spectrum)	300 MWe
7	Canada – U.S.	StarCore Nuclear	High-temperature gas cooled (graphite moderated)	20 MWe
8	U.S.	SMR LLC – a Holtec International Company (SMR-160)	Pressurized water (light-water moderated - PWR)	160 MWe
9	U.S.	NuScale Power (NuScale)	Pressurized water (light-water moderated - PWR)	50 MWe
10	U.S.	Westinghouse Electric (eVinci)	Heat pipe / Nuclear battery (yttrium hydride moderated)	< 25 MWe

Focused Research for Novel SMR Features

- Many different SMR technologies are being developed with novel features
  - ✓ OPEX is limited
  - ✓ much research has been done but safety claims have not been verified
  - ✓ timely computer code qualification activities are needed
  - ✓ understanding of material performance for novel high-temperature materials is required
  - ✓ investigation of fuel properties for novel fuel is needed, including design limits for power, temperature, burn-up and leakage of fission products
  - ✓ there is increased use of passive safety features in the designs

Conclusions

- History has taught us to be prepared for surprises – ongoing research capability is an insurance policy in this regard
- Research capability and availability throughout the lifecycle of a technology is important for success
  - ✓ should not be considered as a “nice to have” or an add-on
- Timely research is necessary to develop a technology and its safety case
  - ✓ experimental facilities
  - ✓ qualified computational tools
- Innovative designs require focused research on novel features
- The role of research should be clear in the shared vision for the success of a nuclear technology

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